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TECHNICAL NOTE

D-1674

THE MAGNETIC FIELD OF THE QUIET-TIME PROTON BELT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON March 1963

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SUMMARY

The distortion of the earth's magnetic field produced by the proton belt is discussed. The magnetic field is calculated numerically, to a first approximation, for an analogous model belt, in a steady state. In the equatorial plane, at the earth's surface, it is estimated that the magnetic field produced by this belt is of order 38 gammas; it is directed southward. The maximum field reduction is of the order of 72 gammas at 4.1 earth radii; this is 15.5 percent of the dipole field intensity at this point. Beyond 6.7 earth radii, the belt increases the earth's field.

CONTENTS

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INTRODUCTION

Recent improved measurements by satellites, especially Explorer XII (1961 υ), have revealed an extensive belt of low energy protons (150 kev-4.5 Mev), encircling the earth (Reference 1). A typical flux distribution along one of the paths of Explorer XII is shown in Figure 1a for magnetically quiet conditions as a function of radial distance from the earth's center: the path considered lay close to the equatorial plane beyond 3.5a (where a is the radius of the earth). In this paper, we calculate the magnetic field produced by a model belt which is similar to the proton belt.

THE MODEL PROTON BELT

When conditions in the belt are steady, the magnetic field produced is determined by the number density n and the velocity distribution $f(v)$ of the particles of the belt, as a function of r_e, the distance from the earth's center along an equatorial radius (References 2 and 3). The velocity distribution involves both the energy spectrum for each kind of particle (protons and electrons), and the pitch-angle distribution; but in the present calculations we shall consider only protons with a particular energy E (or speed v).

The number density distribution is given by:

$$n = n_0 e^{-g_1^2 z^2} \quad (z < 0 \text{ for the inner part of the belt}); \tag{1}$$

$$n = n_0 e^{-g_2^2 z^2} \quad (z > 0 \text{ for the outer part of the belt}), \tag{2}$$

*This report has been published in substantially the same form in *J. Geophys. Res.* 66(7):2645-2647, July 1962.
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where $z = (r_e - r_0)/a$ and r_0 denotes the distance at which n attains it maximum value n_0. The pitch-angle distribution P is assumed to be the same throughout the belt, and to have the form

$$P = A(\alpha) \sin^{\alpha+1}\theta ,$$

where θ denotes the pitch-angle, α is a constant, and $A(\alpha)$ is a normalization factor. We shall adopt the following numerical values:

$$\begin{aligned} r_0 &= 3.2a; & \alpha &= 2.0; \\ g_1 &= 2.990; & n_0 &= 0.6/cc; \\ g_2 &= 0.419; & E &= 500 \text{ kev}. \end{aligned}$$

The number density distribution with the above values of g_1 and g_2 and corresponding to Equations 1 and 2 is shown in Figure 1 with the flux graph. In Figure 2 the measured pitch-angle distributions (Davis, 1962) are compared with our distribution curve P. A more elaborate model belt could be used to fit other distributions of proton number density and velocity along an equatorial radius, but

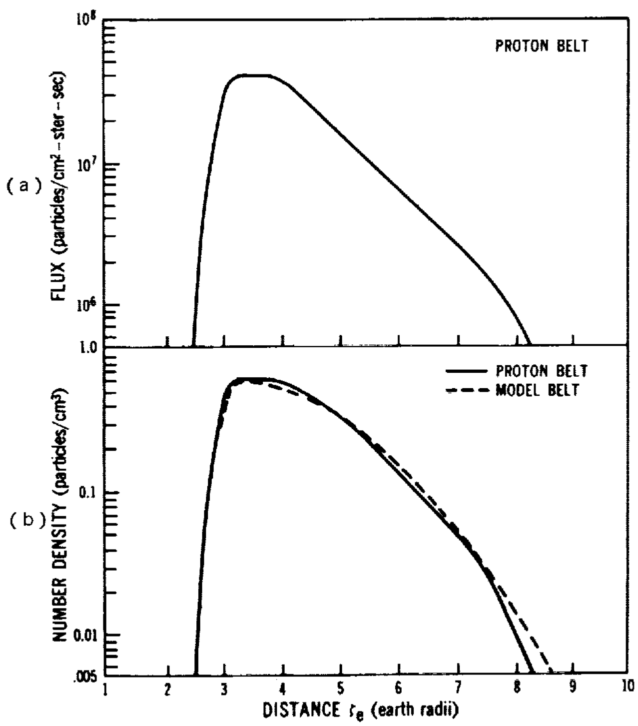

Figure 1—(a) A typical flux distribution in the proton belt, as a function of radial distance from the earth's center; obtained in quiet conditions by Explorer XII. (b) The number density distribution in the model belt and in the observed proton belt.

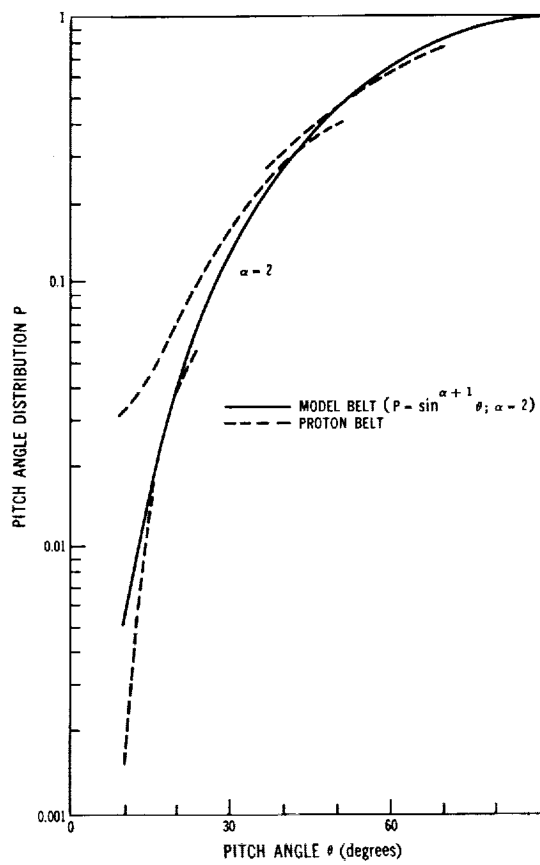

Figure 2—The pitch-angle distribution in the model belt, together with the Explorer XII curves.

the numerical calculations would then be more complicated. It is found, however, that for changes of the parameters g_1, g_2 and α, with the ranges 2.6-2.9, 0.38-0.42, and 2.0-3.0 respectively, the magnetic field produced by the model belt is not substantially affected.

THE MAGNETIC FIELD OF THE MODEL PROTON BELT

The magnetic field ΔF produced by our model belt is calculated for the above parameters by the method given in Reference 2 and used in Reference 3. As we ignore the field distortion caused by the belt, these results represent a first approximation, in which ΔF is proportional to the product n_0E. Let

$$\Delta F = n_0 E \, \Delta F$$

where ΔF is given in gamma if n_0E is in units of kev/cm^3. Note that in our model belt the value of n_0E is taken to be 300 kev/cm^3. The values of ΔF are given in Table 1 for a number of points along an equatorial radius.

Table 1

Values for Δf for various distances r_e from the earth's center (equatorial plane), where $g_1 = 2.990$, $g_2 = 0.419$, $\alpha = 2.0$ and $r_0 = 3.2a$

Distance r_e (earth radii)	Δf (gamma cm^3/kev)	r_e (earth radii)	Δf (gamma-cm^3/kev)	r_e (earth radii)	Δf (gamma-cm^3/kev)
1.0	-0.128	3.0	-0.189	5.0	-0.203
1.2	-0.128	3.2	-0.227	5.5	-0.150
1.4	-0.127	3.4	-0.229	6.0	-0.086
1.6	-0.126	3.6	-0.233	6.5	-0.0243
1.8	-0.125	3.8	-0.237	7.0	0.025
2.0	-0.124	4.0	-0.240	7.5	0.056
2.2	-0.122	4.2	-0.240	8.0	0.071
2.4	-0.120	4.4	-0.237	8.5	0.059
2.6	-0.121	4.6	-0.230	9.0	0.045
2.8	-0.138	4.8	-0.218	10.0	0.023

Figure 3b shows, on a linear scale, the ΔF field along an equatorial radius. The intensity has a minimum value of about -72 gammas at 4.1a, and a maximum value of about +21 gammas at 8.0a. The corresponding field at the earth's surface is about -38 gammas.

Figure 3a gives, on a logarithmic scale, the distortion of the combined field of the earth's dipole and the model proton belt. Within 6.7a the model belt reduced the intensity of the earth's field and beyond this distance increased it. Such a distortion for quiet conditions can be checked by satellite-borne magnetometers, provided that other sources of distortion and higher order moments in the earth's field are known.*

*Further computations of the magnetic field of the radiation belts are available in Reference 4.

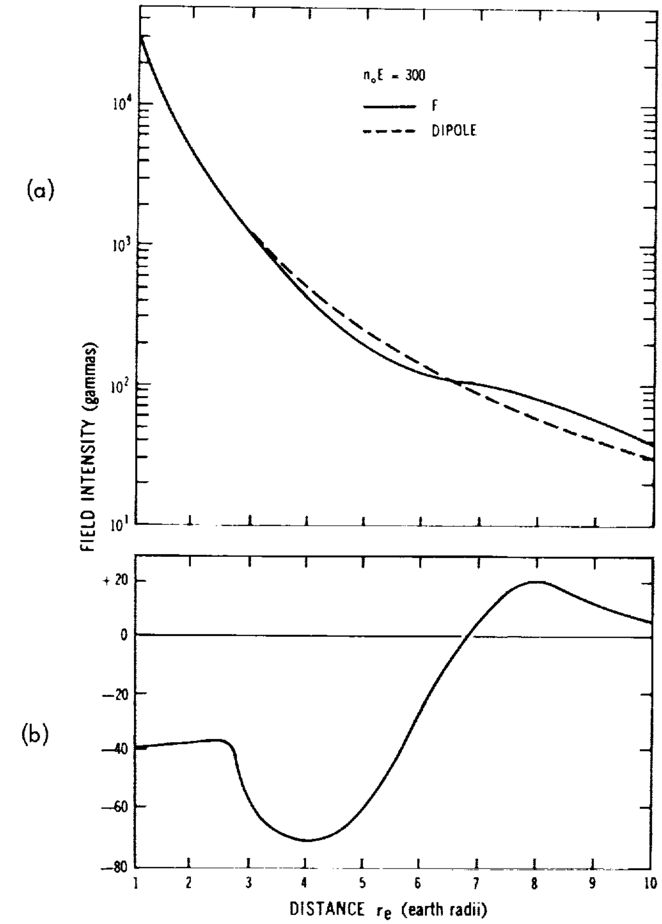

Figure 3—(a) The distortion of the earth's dipole field produced by the model belt in the equatorial plane (b) and the distribution of the magnetic field ΔF produced by the model proton belt in the equatorial plane.

ACKNOWLEDGMENTS

We wish to thank Leo R. Davis for discussing and communicating some of his results to us (Figures 1a and 2) prior to publication. The research reported in this paper was supported by a grant from the National Aeronautics and Space Administration.

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